MISSOURI DEPARTMENT OF NATURAL RESOURCES

CLEANUP LEVELS FOR MISSOURI (CALM) Appendix B

Tier 1 Soil and Groundwater Cleanup Standards

Division of Air and Land Protection
Hazardous Waste Program

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CLEANUP LEVELS FOR MISSOURI (CALM)

APPENDIX B - TIER 1 CLEANUP LEVELS

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1. INTRODUCTION

The purpose of this appendix is to provide a simple look-up table for determining conservatively-derived, risk-based target concentrations for the remediation of voluntary cleanup sites in Missouri. The exposure pathways and formulas used to generate this look-up table are primarily based on the approach outlined in USEPA's 1996 Soil Screening Guidance document (USEPA, 1996d). Missouri-specific technical policy decisions have also been integrated into this approach. These decisions include determination of target risk levels, consideration of resource protection issues, and establishment of values for equation variables used in deriving the look-up table concentration values.

Among the three tiers, Tier 1 cleanup levels generally require the least time and expense to determine, both in user effort, and department review. Tier 1 cleanup levels are generated using very conservative assumptions in order to provide a high level of confidence that they will be protective of human health and the environment at the majority of sites. It is possible that, due to unusual site conditions, the Tier 1 levels would not be protective at some sites. When this situation is indicated, the user should develop site-specific cleanup levels using Tier 2 or Tier 3, either at their own discretion, or at the direction of the department.

2. PROCESS FOR IDENTIFYING TIER 1 CLEANUP LEVELS

2.1. Soil Target Concentrations (STARC)

The following steps outline the process for determining the Tier 1 STARC levels. These steps are graphically represented in the flow chart in Figure B1. Figure B2 illustrates portions of the soil column to which specific clean up targets apply, as described below.

1. The first step in using the Tier 1 table is to determine the contaminants of concern for the site and to find their maximum concentrations in both the shallow soil horizon (0-3ft) and the deep soil horizon (>3feet). This information is gathered as part of the site assessment/ characterization described in section 3.1 of the CALM guidance document.

2. Compare the maximum concentrations of each chemical of concern in the shallow and deep soil horizons with the scenario "A" combined soil ingestion/dermal contact/inhalation pathway (C_{IDI}) soil target concentrations (STARCs) and with the leaching-to-groundwater pathway (C_{LEACH}) STARC values in Table B1. Note: the leaching to groundwater pathway comparison may be disregarded if the following can be demonstrated: laboratory leaching test results obtained using EPA's Synthetic Precipitation Leaching Procedure (SPLP) on samples collected from the area(s) of thesite exhibiting the maximum soil contaminant levels, indicate that no contaminants of concern leach from the soil at levels above the groundwater target concentration

(GTARC) values listed in Table B1.

3. If the concentration of each chemical of concern is below the STARC table values as compared in step 2, proceed to step 10. Otherwise proceed to step 4 below.

4. Using the site scenario flowchart in Figure 1, determine the appropriate site classification. If the concentration of any chemical of concern at the site is above a STARC Table value as determined in the step 2 comparison described above, use the site's exposure scenario ("A", "B", or "C"), to identify a site-specific C_{IDI} STARC value for each chemical of concern in Tables B1 and B2. As part of the site assessment, the user will have already determined which of the exposure scenarios is appropriate for the site.

5. If site scenario "A" is determined to apply, then the Tier 1 cleanup levels have been exceeded, and the user should proceed to step 9. Otherwise, proceed to step 6 below.

6. If a site scenario "B" or "C" is chosen, compare the maximum concentrations of each chemical of concern in the shallow soil horizon with the C_{IDI} and C_{LEACH} STARC values for the appropriate scenario classification. Compare the maximum concentrations of each chemical of concern in the deep soil horizon with the C_{LEACH} values. Again, comparison with C_{LEACH} values may be disregarded if the laboratory leaching test criteria described in step 2 above is met.

7. If the concentration of each chemical of concern is below the STARC table values as compared in step 6 above, proceed to step 10. Otherwise, proceed to step 8 below.

8. If the concentration of any chemical of concern exceeds the STARC table values as compared in step 6 above, then the Tier 1 cleanup levels have been exceeded, and the user should proceed to step 9.

9. Refer to the options described in section 3.4 of the CALM document section labeled "Tier 1 Decision Point".

10. Document all findings in a CALM final report as described in section 3.10 of the main body of the CALM guidance document, and apply for a no further action letter from the department.

2.2. Groundwater Target Concentrations (GTARC)

If the site assessment/characterization identifies groundwater contamination at the site, the user should compare site contaminant levels to the GTARC values in Table B1. If the

GTARC values are exceeded, the user should proceed to section 3.4 of the CALM main body entitled "Tier 1 decision point".

3. RISK - BASED TARGET CONCENTRATIONS

3.1. Purpose

The purpose of the target concentration (TARC) tables is to provide acceptable cleanup levels for soil and groundwater contamination at voluntary cleanup and brownfields redevelopment sites overseen by the Missouri Department of Natural Resources' Hazardous Waste Program, and in evaluation of materials for use as clean fill. These target levels are considered guidance and do not have the force of regulation.

Development of the TARC levels is an iterative process that will be revisited as necessary. New research findings will be considered and changes in toxicity values will be incorporated as information becomes available. The frequency of these updates will be determined both by time and the amount of information to be updated. Major innovations in risk assessment are likely to trigger more frequent updates. The user is encouraged to check with the department for TARC Table updates prior to beginning the CALM process.

3.2 Discussion

Risk can be defined as the possibility of suffering harm or loss. The field of risk assessment attempts to describe and/or quantify the probability of harm occurring. One of the major areas of risk assessment is toxicology, the study of poisons. Virtually every substance, including table salt and distilled water, can be toxic. The amount of risk, however, depends on the toxicity of the chemical and the frequency and duration of exposure. By estimating the potential for exposure and using toxicity data derived from research studies, it is possible to estimate the health risks associated with a specific level of soil contamination.

For carcinogenic chemicals, determination of acceptable soil levels first requires identifying the risk level that is tolerable to the public. After participating in a national debate on this issue, and consulting with lawmakers and other officials, the Missouri Department of Health (DOH) made a policy decision to recommend one-in-one hundred thousand (1×10^{-5}) additional lifetime cancer risk and a hazard quotient of 1 as the maximum acceptable level of risk.

Figure B1. Process For Determining Tier 1 Soil Cleanup Levels

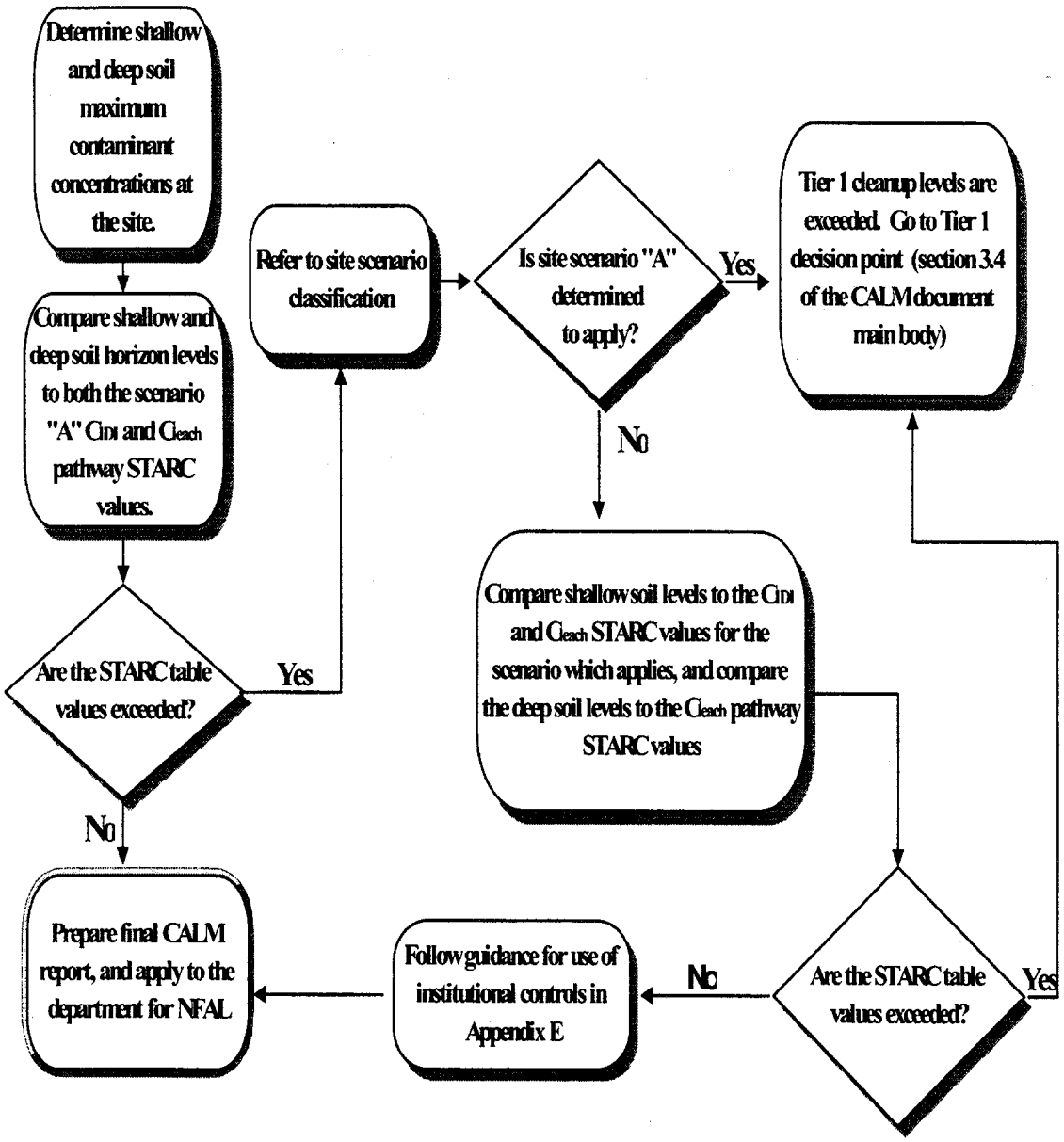
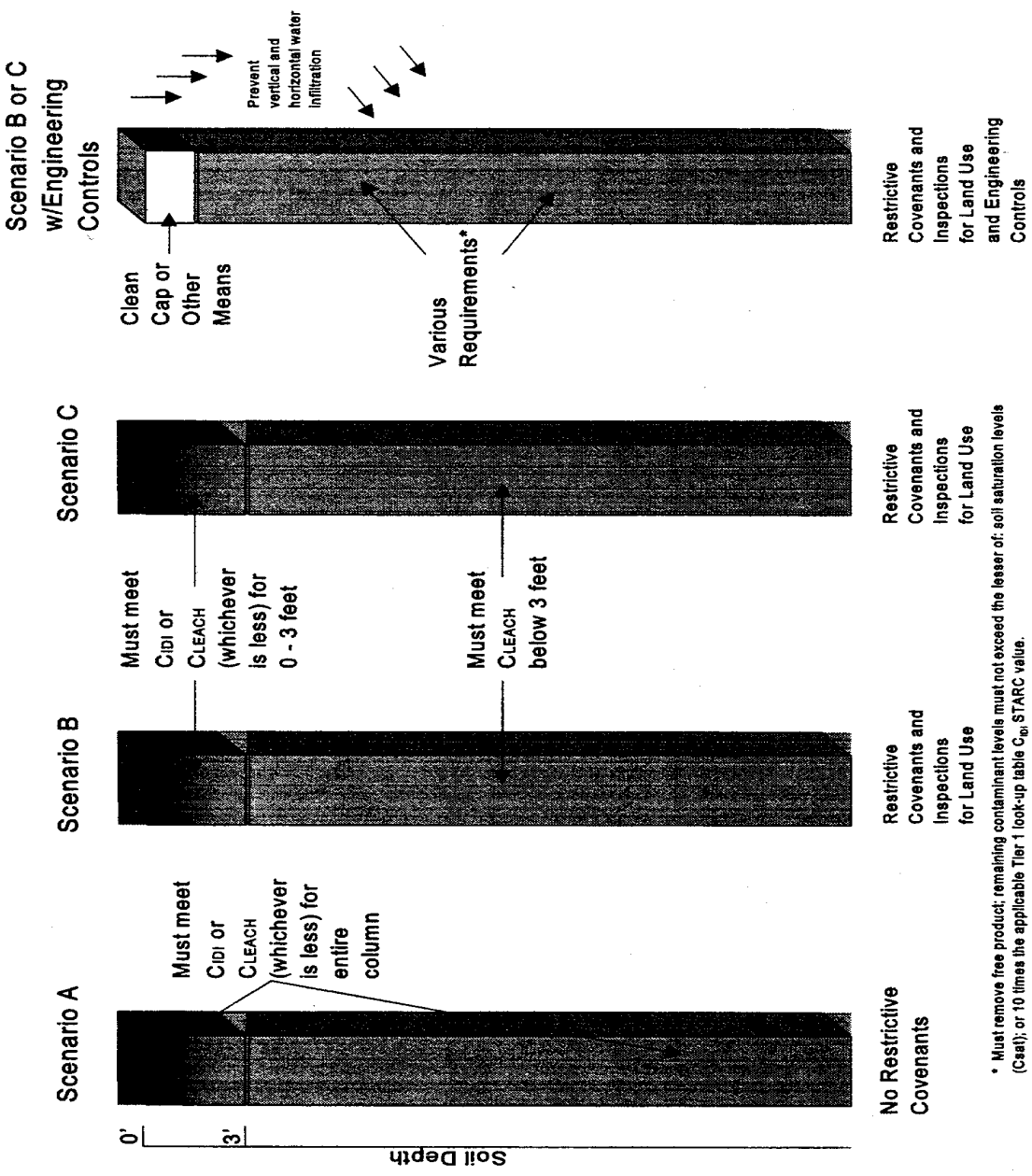


Figure B2: Applying C_{IDI} and C_{LEACH} to the Soil Column



The default exposure parameters used for Tier 1 for the various land use (exposure) scenarios are summarized in Table A2. While most of the parameters are assumptions used by the EPA Superfund Program, others are specific to the Missouri Department of Health or MDNR. Each scenario has a unique set of default parameters because each scenario represents a different set of exposure assumptions. For example, the assumption is made that children will not be routinely present on the grounds of an access-controlled facility (Scenario C), and that employees of the facility work five days a week and get a two-week vacation.

The values used for each default exposure parameter depends on the receptor and the exposure scenario. In most cases, the receptor (target organ) for noncarcinogenic and carcinogenic risk is different. The cleanup levels are calculated based on an estimate of the frequency and duration of exposure for the subpopulation at highest risk.

3.3 Methodology

This guidance provides three sets of cleanup levels for soil within each tier. The values generally become progressively higher (less restrictive) as the user moves from scenario "A" toward the more controlled setting in scenario "C". This is due to the fact that each successive land use category represents a scenario with less potential for human exposure.

Except as noted in the discussions below regarding C_{sat} and some of the alternately derived TARC contaminants, the soil levels for each category are human health-based, and are primarily derived from the potential for adverse health effects from soil ingestion, dermal contact, inhalation, leaching to groundwater, and groundwater ingestion.

For chemicals which may carry a carcinogenic risk, soil levels are calculated for both carcinogenic and noncarcinogenic risks whenever possible. The more protective (lower) of the two soil concentrations is then used. Generally, the carcinogenic level will be lower. However, for some weak carcinogens, a noncancer endpoint, such as liver damage or increased kidney weight, may be more sensitive.

A. Soil Saturation (C_{sat})

Soil saturation occurs at the point where the soil (including soil particles, pore space, and soil moisture) has absorbed all the liquid phase contaminant it can physically hold. When the concentration in soil exceeds soil saturation, non-aqueous phase liquid (NAPL) is present (commonly referred to as "free product"), which can migrate to other media. When NAPL is present, assumptions regarding the pathways considered as part of the Tier 1 STARC evaluation (soil ingestion, dermal contact, vapor inhalation, leaching to

groundwater, and groundwater ingestion) become less valid. The presence of NAPLs may result in enhanced groundwater and/or surface water contamination, and/or soil gas or liquid which can migrate into basements and other below grade structures. Free product may also pose a hazard to excavators and utility workers. It should also be noted that for some contaminants, concentrations below both the C_{sat} and TARC could also present aesthetic concerns such as odors and tastes in drinking water.

It is possible with contaminants of relatively low toxicity, that the calculated C_{sat} value could be lower than the C_{IDI} or C_{LEACH} values. When this occurs, the C_{sat} value becomes the STARC. This applies only to contaminants which are liquids in their pure state at temperatures expected to occur in the environment (those with melting points at or below 30°C). Table B1 includes a column indicating whether the cleanup level for each contaminant is based on risk calculations, or on the C_{sat} value. The C_{sat} values were calculated using equation 7 in Appendix A, Table A1.

B. Ingestion/Dermal Contact/Inhalation Pathway Soil Target Concentrations (C_{IDI})

(1) Pathways and Assumptions

Various modeling equations have been developed for human and ecological exposure pathways for contaminated soil. The pathways chosen for CALM represent what the department considers to be the major pathways of human exposure: passive ingestion of soil, inhalation of contaminated dust particles, inhalation of vapors of volatile contaminants, and dermal absorption. For these pathways, C_{IDI} target concentrations are applied to only the top 3 feet of the soil column, since inhalation, ingestion, and dermal contact are unlikely to occur from contaminants present in lower depths (Figure B2). The one exception is in the case of a Scenario A cleanup. For Scenario A, the C_{IDI} cleanup levels are applied to the entire soil column. Since it is undesirable to require institutional controls for sites classified as Scenario A (sites suitable for uncontrolled use with no use restrictions), it is necessary to remediate even deeper soils to the C_{IDI} target. This will ensure that future excavation will not bring deeper soils contaminated above C_{IDI} levels to the surface where exposure could occur. For Scenarios B and C, if soil below 3 feet is contaminated above inhalation, ingestion, and dermal contact target concentrations, and will remain in place rather than be actively remediated, institutional controls (subject to the provisions in Appendix E) may be used to prevent uncontrolled excavation of the deeper soil.

For Tier 1, assumptions have been made for a variety of parameters, including averaging time, body weight, exposure duration and frequency, inhalation and

ingestion rates, and soil and groundwater properties. The soil target concentrations for Tier 1 are calculated using a single equation which takes into account the combined risk associated with all of the pathways (ingestion, dermal contact, inhalation). This results in a more realistic analysis than addressing the pathways separately.

(i) Soil Ingestion

For many chemicals, soil ingestion is the most significant pathway. Humans incidentally ingest soil that is attached to foods, especially fruits and vegetables. They also incidentally ingest soil when they eat "finger foods." People who wash their hands frequently tend to ingest smaller amounts of soil from this source, and children tend to ingest higher amounts.

For scenario "A", children are assumed to be the most sensitive population. The noncancer calculation for scenario "A" assumes a child could be exposed, and incidentally ingest 0.2 grams of soil per day, with an exposure frequency of 350 days per year. For carcinogenic risks, an adult is assumed to be the receptor, since this yields more conservative values. The carcinogenic calculation for scenario "A" assumes a 30 year exposure; 6 years as a child and 24 years as an adult.

For scenario "B", children are assumed to be the most sensitive population. The noncancer calculation for scenario "B" assumes a child incidentally ingests 0.1 grams of soil per day, with an exposure frequency of 250 days per year. For carcinogenic risks, an adult is assumed to be the receptor. The carcinogenic calculation for scenario "B" assumes a 30 year exposure at a daily ingestion of 0.1 grams of soil per day, and otherwise uses the same exposure variables as for scenario "A".

Scenario "C" is for controlled sites where children do not have access. Scenario "C" calculations use adult values only and assume a 5 day a week, 25 year occupational exposure for both carcinogenic and noncarcinogenic effects.

(ii) Dermal Contact

The dermal contact pathway considered in CALM models exposure to contaminants associated with soil particles which adhere to the skin. The adherence factor (AF), expressed as mg/cm^2, quantifies the mass of soil particles released at a site which adhere to the skin surface. A default value

for AF of 1.0 mg/cm^2 is used based on EPA guidance. The tendency of an individual contaminant to disassociate from the soil particle and absorb into the skin is often expressed as a dermal absorption factor (ABS). The dermal absorption factor is expressed as a percent of the contaminant which, if present in direct contact with the skin, will be absorbed into the body. Dermal absorption is a significant route of exposure for some chemicals, especially volatile organics. Metals tend to be poorly absorbed through the skin, while most semi-volatile chemicals falling in between. Pesticide absorption is quite variable, some are readily absorbed through the skin, while others are comparable to metals. Where chemical specific data was not available, the following defaults were used as dermal absorption factors.

Volatile Organics	30%
Semi-volatile Organics	10%
Metals	1%
Pesticides	30%

Slope factors for the dermal contact pathway are largely not available. Therefore, oral slope factors were converted into dermal slope factors using the oral absorption efficiency (OAE). This conversion is necessary to convert an oral (or administered) dose into a absorbed dose. The OAE value is chemical specific, however very few chemicals have been studied. Where available, the chemical-specific value is used, while a default of 100% is used for chemicals with no known OAE.

The skin surface areas used in the calculations were 4714 cm^2 for an adult and 4236 cm^2 for a child. The total surface area for an adult is based on exposure to the hands, arms, face, and head. The child's surface area includes hands, arms, face, head, and lower legs.

(iii) Inhalation

As with ingestion, children are often the most sensitive to the effects of contaminant inhalation. The CALM scenarios assume an inhalation rate of 20 m^3/day for adults and 10m^3/day for children. Because a child has a much lower body weight than an adult (15 kg versus 70 kg), if a child were exposed to the same dose of contaminants through the inhalation pathway as an adult, the effect would be as if the child received almost five times the dose per kilogram of an adult.

Since Scenarios A and B represent less controlled settings where exposure

may occur for most of the day, the same inhalation rates were used. For Scenario C, the child inhalation rate was not used, since children should not be routinely present. The adult inhalation rate remains at 20 m^3/day because, while workers are only assumed to be onsite for 8 hours per day, they are assumed to be actively working, and thus will breathe at a higher than sedentary rate.

The soil to air volatilization factor (VF) is used to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. The VF used in the CALM formulas is based on the Jury model, which is an EPA approved model that has been verified through field testing (EPA, 1996c). In order to calculate a generic VF for use in the TARC lookup table, default assumptions are needed for a number of variables including the site size, soil bulk density, fraction of organic carbon in soil, and many others. The default for the inverse of mean contaminant concentration at center of a square source (Q/C), was selected from EPA's Soil Screening Guidance based on dispersion modeling using a 0.5 acre square site and meteorological conditions from Lincoln, Nebraska. The actual default values used to calculate a generic VF are listed in Appendix A, Table A2 and are based on default assumptions used by EPA (USEPA, 1996c).

The formulas also utilize a particulate emission factor (PEF) which relates the concentration of contaminants in soil to the concentration of dust particles in air. As with the VF, in order to calculate a generic PEF for use in the TARC lookup table, default assumptions are needed for a number of variables. These include average wind speed, the fraction of vegetative cover at the site, and others. The default values used for these variables are listed in Appendix A Table A2, and were also selected based on default assumptions used by EPA (USEPA, 1996c).

C. Leaching To Groundwater Pathway Soil Target Concentrations (C_{LEACH})

(1) Pathway

Contaminants present in the soil or unsaturated zone are subject to leaching as infiltrating rainwater percolates downward though the soil column. Depending on the contaminant type(s), soil properties, and other site conditions, leached contaminants may reach the saturated zone, potentially exposing human and ecological receptors to groundwater contamination. In order to establish soil cleanup levels which are protective of groundwater resources, the department chose to use a set of simplifying formulas and assumptions which are intended to approximate the physical processes involved in soil contaminant leaching to

groundwater. The C_{LEACH} value may be interpreted as a soil contaminant concentration which (within the limitations of the formulas and assumptions) if allowed to remain, would leach to the saturated zone and result in a groundwater concentration at or below the groundwater target concentrations (GTARC) found in Table B1.

The equations used in CALM to model the leaching of contaminants from the soil to groundwater can be conceptually reduced to two very simplified and related steps. These processes, however, should not necessarily be thought of as occurring in stepwise fashion; they likely occur simultaneously. First, contaminants partition from the vadose zone soil into the soil pore space water. This process is represented in CALM by a simple linear soil/water equilibrium partitioning equation (the bracketed portion of formula 8 in Table A1, Appendix A). The dissolved contaminant then migrates through the soil column and mixes with water in the saturated zone.

A number of physical and chemical processes may affect the contaminant as it migrates within and through the soil column, including sorption to unsaturated or saturated zone solids, chemical or biological degradation, volatilization, lateral movement in seams of high permeability, and dispersion with infiltrating recharge, among others. Representing all of these physical processes mathematically would be very complex. Therefore these physical processes are simplified in CALM by using a mixing zone equation derived from a water balance relationship (formulas 10 and 11 in Table A1, Appendix A).

(2) Assumptions

Leaching of contaminants through the soil column into groundwater is an extremely complex interaction. No model or set of equations can adequately represent these interactions for any specific set of site characteristics, let alone for all sites in Missouri. In order to provide the simple look-up table approach used in Tier 1, a number of simplifications and assumptions were necessary in order to facilitate the calculations of the C_{LEACH} STARC values. The simplifying assumptions inherit in these formulas are listed in Figure A1, Appendix A. Specific assumptions regarding the values chosen for the variables in these equations are listed in Figure A2, Appendix A.

In general, an attempt was made to select values for the formula variables from within the range of expected natural variability which result in conservative estimates of C_{IDI} and C_{LEACH} values. It is not expected that this particular set of assumptions will apply specifically to any one site; rather, they are intended to provide a conservative set of cleanup targets which, if attained, would be protective

of human health and the environment across a broad range of site conditions in the state.

The C_{LEACH} values are chemical-specific since they are based on the soil/water partition coefficient, Henry's Law constant, and aqueous solubility of each contaminant. The C_{LEACH} calculations, however, also require assumptions as to the soil bulk density, soil organic carbon content, and air and water content of the soil. Estimates for these parameters were made based on EPA guidance, modified for Missouri conditions (see Table A2).

Because of the uncertainty resulting from the wide variability in subsurface conditions that affect leaching of contaminants from the soil into groundwater, the CALM document does not specify default values for the variables used to derive the dilution factor (Appendix A, formulas 10). Instead, a default dilution factor of 20 has been selected based on an analysis conducted by EPA. A discussion of the basis for the default dilution factor may be found in the EPA Soil Screening Guidance Technical Background Document (USEPA, 1996c). The user is encouraged to develop a site-specific dilution factor using field data collected from the site where possible.

Calculation of the C_{LEACH} also requires groundwater target concentrations (GTARC) which are found in Table B1. The Tier 1/ 2 GTARC values are generally based on the EPA maximum contaminant levels (MCLs) for drinking water, where available. The MCLs are chosen based on the conservative assumption that all groundwater is a potential current or future source of drinking water. The department recognizes that there are some sources of groundwater which will never be used as a source of drinking water due to factors such as hydrologic yield limitations or natural water quality limitations, and is currently investigating the feasibility of developing a data collection and analysis process which could be used to identify these groundwaters.

Note that the C_{LEACH} column of Table B1 is blank for several contaminants. Data gaps in the chemical constants required, K_{oc}, H', and/or GTARC, prevent calculation of a C_{LEACH} value for some contaminants. The department will fill in these data gaps as information is identified and collected. If the soil contaminants of concern for a given site include those in Table B1 for which no C_{LEACH} value is given, the department may request that the user investigate the availability of the missing chemical constant(s) needed to calculate a C_{LEACH} value for the site. If the required chemical constants are not available, they may be estimated, or some other approach proposed to evaluate this pathway.

The leaching pathway is handled differently for some of the contaminants for which alternately derived TARC values are used. These are described in section 5 below.

4. REFERENCE DOSE, REFERENCE CONCENTRATION, AND SLOPE FACTORS

Most of the reference doses, reference concentrations, and carcinogenic slope factors are from EPA's IRIS database. The others are from EPA's HEAST database or from documents produced by EPA's toxicology group in Cincinnati (NCEA). In some cases, no slope factor is available for a carcinogen. In these instances, only a noncarcinogenic value is calculated. In cases where a slope factor is available but there is no reference dose, only the carcinogenic value is calculated. The toxicological values used in the CALM formulas are in Table A2.

5. ALTERNATELY DERIVED SOIL TARGET CONCENTRATIONS

There are some chemicals and/or families of chemicals for which the health-based formulas in Appendix A are not used. For these chemicals, sources, other than EPA's IRIS database, EPA's HEAST database, and documents produced by NCEA, were used for reference doses and carcinogenic slope factors. Alternatively derived cleanup levels for these chemicals are included in Table B1, and indicated with numeric superscripts. An explanation of how each is derived is included in the following discussion.

5.1 Arsenic

The arsenic level provided is based on noncarcinogenic effects to an adult (RfD-adult). The values found by using childhood variables and assessing carcinogenic risk (as is done for most other contaminants) are well below naturally occurring background concentrations for most Missouri soils (Tidball, 1984). Rather than use these low cleanup target levels which would rarely be achievable, a decision was made to use more realistic values. Consequently, the RfD-adult calculation is used for all but Scenario "C" which was calculated based on risk from carcinogenic effects.

5.2 Chromium

The total chromium STARC values are alternately derived because there are dramatic differences in toxicity based on the valence state of the metal. Trivalent chromium (+3) is an essential trace nutrient, while some forms of hexavalent chromium (+6) are known to be carcinogenic. Whether the chromium is hexavalent, trivalent, or a combination of the two is site specific. Among the factors influencing chromium speciation are the source of the chromium, and the soil conditions (pH, oxidizing/reducing conditions, cation exchange capacity). If, for example, the chromium at a site is derived from tannery sludge, one could assume that most of the chromium is trivalent. On the other hand, if the chromium is present due to electroplating, it should be assumed that at least some of the chromium is hexavalent.

Depth and volume may also play roles, since chromium-containing wastes placed on the surface are likely to be quickly oxidized to the trivalent state, while chromium-containing waste that is buried or placed in large stockpiles is more likely to remain hexavalent. If the source of the chromium is unknown, it should be assumed that hexavalent chromium may be present. For calculation of the STARC lookup table values, the conservative default assumption is made that 90% of the total chromium concentration detected at all sites is trivalent and 10% is hexavalent. This yields Tier 1 C_{IDI} values ranging from 1300 (Scenario A) to 2700 mg/kg (Scenario C). The C_{LEACH} value, however is based on the assumption that all chromium is hexavalent. Since trivalent chromium is almost completely immobile in the environment, including it in the C_{LEACH} calculation generates an unrealistically high value (e.g. 100% chromium).

5.3 Copper

There is currently no published reference dose for copper. Therefore, the copper STARC values given in Table B1 are derived from 1) the EPA public drinking water action level of 1.3 mg/l, and 2) the assumption that 60% of an individual's exposure to copper comes from incidental soil ingestion, 20% comes from drinking water ingestion, and 20% comes from other sources (e.g. dermal contact and inhalation).

A drinking water consumption of 2 liters per day of water containing 1.3mg/l copper yields a daily dose of 2.6 mg/day. Using this daily dose, a reference dose of 0.037 mg/kg/day for a 70kg adult can then be calculated. Extrapolating this dose to a soil ingestion value, assuming 100mg/day incidental soil ingestion, and multiplying by 3 to adjust from 20% of exposure (the drinking water assumption) to 60% of exposure (the soil ingestion assumption), yields STARC values ranging from 1110 mg/kg (Scenario A) to 4700 mg/kg (Scenario C).

5.4 Cyanide

Cyanide is toxic through a non-cancer pathway and the only toxicological data available is an oral reference dose. Extrapolation of the oral dose to dermal/inhalation pathways is not recommended. Therefore, the Tier 1 cyanide values are based on the oral pathway only.

5.5 Lead

The lead levels provided in this document are based on EPA's Screening Level For Lead Program (also known as the Adult Lead Model and the Pregnant Worker Model), and the Integrated Exposure Uptake Biokinetic (IEUBK99D) model (USEPA, 1994a). Other sources, including epidemiological studies, were used to verify the model results. The exposure assumptions and default values used for each model are listed below.

Figure B3. Screening Level For Lead Program, Version 1.0 Model Parameters and Defaults

Parameter	Definition (units)	Adult Default
PbB_{95} fetal	95th percentile PbB in fetus (ug/dl)	10
R	Mean ratio of fetal to maternal PbB	0.9
GSDi	Individual geometric standard deviation (heterogenous population)	2.1
PbB0	Baseline blood lead value (ug/dl)	2.2
BKSF	Biokinetic slope factor (ug/dl per ug/day)	0.4
IRs	Soil ingestion rate (g/day)	0.05
IRd	Dust ingestion rate (g/day)	0
EFs	Soil exposure frequency	250
AFs	Absolute Absorption Fraction of Lead in soil	0.12

Figure B4. IEUBK99D Model, Parameters and Defaults

Parameter	Default
Soil Lead Level	260 mg/kg
Indoor Dust Lead	200 mg/kg
Soil/Dust Weighting Factor	0.45
Target Distribution	95% of Population below 10ug/L
Soil Ingestion Rate age <1year and 4-7 years age 1-4 years	 100 mg/day 200 mg/day

Figure B4. IEUBK99D Model, Parameters and Defaults

Parameter	Default	
Drinking Water Concentration	4 ug/L	
Mother's Blood Lead at Birth	2.5 ug/L	
Bioavailability		
Soil	30%	
Dust	30%	
Water	50%	
Diet	50%	
Indoor Air Lead Concentration	0.03 ug/m^3	
Outdoor Air Lead Concentration	0.1 ug/m^3	
Dietary Intake		
Age	Ingested(ug/day)	Water (L/day)
0-1	5.53	0.20
1-2	5.78	0.50
2-3	6.49	0.52
3-4	6.24	0.53
4-5	6.01	0.55
5-6	6.34	0.58
6-7	7.00	0.59

Hours Outdoors/Day

Age	Hours	Ventilation Rate m^3/day	%Lung Absorption
0-1	1	2	32
1-2	2	3	32
2-3	3	5	32
3-4	4	5	32
4-5	4	5	32
5-6	4	7	32
6-7	4	7	32

The scenario B and C STARC values are the same (660 mg/kg) because they are both based on the conservative assumption that a pregnant worker is present on site for 250 days/year consuming 50mg/day soil. This assumption leads to a more conservative STARC value (660 vs 690 mg/kg) for Scenario B than that calculated using the assumptions of a child ingesting 100mg/day soil for 250 days/year.

5.6 Methyl Tertiary Butyl Ether (MTBE)

No available data were located regarding an EPA-recognized reference dose for MTBE. Therefore the Department of Health consulted toxicology studies from the literature which were used to set the EPA drinking water guidance value of 40 ug/l. A reference dose of 0.006 mg/day was selected based on these studies. The reference dose was then used to calculate the C_{IDI} cleanup values using the same formulas and procedures as is used for the other non-alternately derived contaminants.

5.7 Polychlorinated Biphenyls

The Tier 1 STARC values were based on toxicity data for Aroclor 1254. The slope factors used were selected from a recent EPA publication (USEPA, 1996a). This assumption is conservative because among the commercially used Aroclors, this congener has the highest carcinogenic slope factor. The user may justify use of a different slope factor based on site-specific Aroclor or congener analyses at Tiers 2 or 3 as described in Appendices C and D. For PCBs, no C_{LEACH} value is calculated. The department considers the CIDI values in Table B1 to be protective of the leaching to groundwater pathway in most cases. Further evaluation of leaching potential may be required at some sites based on site-specific conditions.

5.8 Polynuclear Aromatic Hydrocarbons

Alternately derived C_{IDI} values were calculated for all of the carcinogenic polynuclear aromatic hydrocarbons listed in Table B1. These PAHs, however, do not have individual carcinogenic slope factors. Instead, EPA has ranked their toxicities relative to benzo(a)pyrene using a relative potency factor (RPE). The levels listed were derived by multiplying the RPE by the STARC values generated for benzo(a)pyrene which were calculated using the health based formulas in Table A1. The RPEs were generated using mouse skin carcinogenesis assays conducted by EPA (USEPA, 1993d). The RPEs are listed in Section 2.10 of Appendix C.

5.9 Total Petroleum Hydrocarbons

Total petroleum hydrocarbons (TPH) is a complex mixture which includes many individual compounds. Insufficient health-based data are available to calculate either a reference dose

of carcinogenic slope factor. However, the department considers it important to include soil target concentration for TPH. Experience accumulated by the department from overseeing the cleanup of over a thousand petroleum release sites in Missouri, has shown that TPH levels are valuable indicators of gross hydrocarbon contamination, and are useful in establishing cleanup goals for aesthetic and other non health-based considerations.

The department is aware of efforts by the Total Petroleum Hydrocarbon Criteria Working Group (a national ad hoc consortium of private industry, state and federal regulators, and consulting firms) and others to develop scientifically defensible risk-based cleanup levels for TPH. These methods are currently under review, and will be considered for possible inclusion in a future CALM revision.

The soil target concentrations for TPH were taken from the MDNR Hazardous Waste Program Tanks Section March 1996 Closure Guidance Document, Table 4 - LUST Soil Cleanup Guidelines for Undisturbed Soil. TPH values for each scenario were selected from across the range of TPH matrix values found in the Closure Guidance Document. For TPH, no C_{LEACH} value is calculated. The department considers the Table B1 CIDI values to be protective of the leaching to groundwater pathway. Further evaluation of leaching potential may be required at some sites based on site-specific conditions.

6. ALTERNATELY DERIVED GROUNDWATER TARGET CONCENTRATIONS

The department has extensive experience with several contaminants due to their presence in petroleum products, and prevalence in the environment. These contaminants include toluene, ethylbenzene, xylenes, total petroleum hydrocarbons (TPH), and methyl tertiary butyl ether (MTBE). Empirical evidence based on the department's experience in overseeing several hundred petroleum release cleanups involving groundwater contamination, have indicated that the MCLs for these compounds are not protective of safety and aesthetic groundwater qualities. Therefore, the department has developed alternate groundwater cleanup target values for these contaminants as shown in Table B1. These target values have been in use by the department for over 5 years and have been determined to be protective of human health and the environment as well as safety and aesthetic qualities for groundwater.

7. CLEANUP LEVELS FOR SURFACES AND BUILDING INTERIORS

7.1 Asbestos Abatement

Clearance criteria for asbestos abatement projects which occur within the confines of a building are specified at 10 CSR 10-6.240(H). Any deviations from this clearance criteria must be approved by the department.

7.2 Lead Abatement

For lead abatement projects which occur within the confines of a building the clearance criteria for dust wipe samples are as follows;

Scenario A

50 micrograms of lead per square foot for uncarpeted floors
250 micrograms of lead per square foot for window sills
800 micrograms of lead per square foot for window wells

Scenarios B and C

200 micrograms of lead per square foot for floors
500 micrograms of lead per square foot for window sills
800 micrograms of lead per square foot for window wells

Any deviations from this clearance criteria must be approved by the department.

Note: The Scenario A clearance criteria are derived from 40 CFR 745.65(b), as proposed in the June 3, 1998 *Federal Register*. The Scenario B and C clearance criteria are derived from the Missouri Office of Administration's Lead Abatement Specifications.

7.3 PCB-Contaminated Structures

For PCB-contaminated concrete, the cleanup criteria shall be 10 ppm for destructive core sampling and 10 µg/100 cm^2 for surface wipe sampling. Since concrete is permeable, destructive core sampling or it's equivalent is required for PCB-contaminated concrete. The wipe sampling may be optional. The department may consider higher cleanup criteria for PCB-contaminated concrete if the concrete is effectively encapsulated with an impermeable surface coating. In this case, a restrictive covenant would be required to ensure long term maintenance of the surface coating.

For PCB contamination on impervious solid surfaces, such as a metal wall, the cleanup criteria shall be 10 µg/100 cm^2 for a surface wipe sample.

Note: The 10 µg/100 cm^2 criteria is derived from EPA's PCB Spill Cleanup Policy, 40 CFR 761, Subpart G. EPA's Spill Cleanup Policy does not prescribe destructive core sampling for PCB-contaminated concrete. The department beleives that wipe sampling alone is not sufficient to verify cleanup of PCB-contaminated concrete. It is possible to remove PCBs from the surface of the concrete through solvent washing and leave behind significant PCB

contamination deeper in the concrete. With time, PCBs may again migrate to the surface, creating a potential exposure. This scenario illustrates the need for destructive core sampling.

8. LIMITATIONS TO THE RISK-BASED APPROACH

The methodology used in CALM for determining health-based levels is founded on current knowledge of hazardous substance exposures. There are, however, several limitations to this methodology, at least for some chemicals. Some of these limitations are discussed below.

8.1 Toxicological Limitations

These risk-based cleanup levels found in Table B1 may not be protective of certain reproductive functions. A developing fetus is particularly sensitive to some toxic chemicals. A modest dose of certain mutagens, delivered at a critical stage of development, can potentially result in damage to a fetus. For some of these chemicals, avoidance during pregnancy alone may not be sufficient, since some chemicals may be stored in the mother's body for several years, and then transferred to the fetus/infant during pregnancy and lactation. Very limited data are available for these interactions. Therefore, it was not possible to explicitly consider them in the development of the risk-based cleanup levels.

There is some uncertainty associated with the assumption that any exposure to a carcinogen increases the risk of developing cancer. Under the current methodology, an exposure to 100 mg/day for 10 days is considered to be equal to an exposure to 10 mg/day for 100 days. For a variety of reasons, this may not be true. For instance, if a chemical causes cancer by overwhelming a detoxification pathway, the larger dose rate may result in DNA damage while the lower concentration may not. Conversely, if the body absorbs a lower percentage of the higher dose, which is often the case, then the lower dose/ longer duration exposure would result in a larger effective dose.

There are many sources of uncertainty in deriving acceptable soil cleanup levels. While quantitative data on human exposure to some hazardous chemicals is available, the majority of toxicological data is derived from animal (usually rodent) studies. There are numerous uncertainties involved in extrapolating from rats to humans, because of differences in metabolism, life span, and body size. In addition, most rodent carcinogenic evaluations involve extrapolation from very high doses to low doses. Depending on the mechanism of carcinogenesis, this may or may not be appropriate. In time, mechanistic data may be available to enable the recalculation of carcinogenic potential for some chemicals, allowing this source of uncertainty to be reduced.

Individual variability includes not only age, gender, and body weight, but extends to genetic

differences that can have important metabolic and toxicological effects. These differences are sometimes individual, and sometimes related to gender, race, ethnicity, or area of origin. Recent studies have shown that these genetic differences can result in variations in enzyme levels that can greatly alter the rate at which the body clears many chemicals. Slow secretors can quickly build up a toxic dose even though most individuals would show no symptoms.

The Tier 1 CALM cleanup levels are based on single chemical releases and exposures. Some chemicals, however, may have additive or multiplicative effects. For instance, two chemicals which can cause liver damage may cause twice the damage if administered in combination, or could result in even greater damage if one chemical acted to prevent excretion of the other or enhanced its toxicity. These synergistic effects have been noted for some combinations, such as asbestos and smoking, but in most cases the effects chemicals may have when administered in combination are simply not known.

Further, some chemicals have been shown to have antagonistic effects. For instance, selenium and arsenic tend to counteract each other. Arsenic is both an acute poison and a carcinogen. Selenium is an essential trace nutrient, but is toxic at high doses. A potentially fatal dose of either compound, when administered with the other, will result in far less serious effects, and may not produce any noticeable adverse effects.

For many contaminants, dermal reference doses are extrapolated from oral reference doses. There are cases, however, where this will underestimate the potential for an adverse effect. For instance, a chemical may cause health effects when applied dermally, i.e. (dermatitis, allergy, skin cancer) that it does not cause when ingested. Using an oral reference dose does not necessarily reflect these health concerns. Unfortunately, few dermal reference doses exist, and it is better to use a value which underestimates the risk than not to evaluate the risk at all.

The assumptions for carcinogenesis used in this document are valid for most cancers that become more common with age. They are less valid, however, for cancers which tend to strike children and young adults. Unfortunately, there is not enough information about the latency periods and mechanisms of carcinogenesis to develop better models for most chemicals.

8.2 Exposure Assessment Limitations

Assumptions made during exposure analysis generate another area of uncertainty. While some exposures can be reasonably well documented, others can be extremely difficult to verify. For example, individuals who trespass onto and receive exposure from a contaminated site are unlikely to be accounted for in an exposure assessment when their admissions could lead to criminal charges. Even more basic is the difficulty in estimating

the exposure of populations who, because they are individuals, have different lifestyles and habits. Even when this information is available it must be extrapolated, and thus has a degree of error. Development of more and better biological markers of exposure would help, but would still only be relevant to past exposure.

There is also uncertainty because of physical variability among individuals in a population. To perform an assessment, it is necessary to make assumptions about the person or people who are, or might be exposed. It is theoretically possible to perform a specific risk assessment for each person who might be exposed to a particular site, in most instances, however, it is not practicable or feasible. Even at sites where it would be possible, it would be labor-intensive, and would defeat the purpose of the tiered approach. For this document, DOH generally used the default variables used by EPA. These variables represent reasonable averages or reasonable upper-bound values. For example, the adult body weight used is 70 kilograms (154 pounds). Obviously, not everyone weighs the same amount. If given the same amount of a compound, an adult who weighs more than 70 kg is generally less likely to exhibit symptoms than an adult weighing less than 70 kg. Lower body weight is the primary reason children are often the most sensitive subpopulation.

Many chemicals alter the leaching potential of other chemicals. A solid material may be virtually insoluble in water, but highly soluble in some alcohols, solvents, or acids. Where numerous chemicals have been released at the same site, the C_{LEACH} values provided in this document may underestimate the potential for the spread of contamination. In this situation, a quantitative ecological risk assessment or more detailed health risk assessment under Tier 3 may be justified.

The dermal absorption values used in CALM assume that a chemical is in direct contact with uncovered skin. Some studies have shown that some chemicals can be virtually 100% absorbed through the skin. These studies, however, place the chemical on the skin and under a watch glass. This method does not allow the chemical to volatilize and is, therefore, not reflective of most exposures. This research does, however, demonstrate that certain conditions (i.e. prolonged exposure to wet, soiled, contaminated clothing) could significantly increase exposure from this pathway.

Perhaps the greatest uncertainty in exposure assessment is in estimating future exposure. Unfortunately, this is also an important part of an assessment, since many contaminants may

Table B1. Soil and Groundwater Target Concentrations (STARC and GTARC)

Chemical	CAS #	Soil Target Concentrations (STARC) (see Appx. B, Sec. 2 & Fig. B2 for guidance in selecting cleanup levels)				Groundwater Target Concns (GTARC) mg/l
		Direct Exposure (Ingestion/Dermal/Inhalation) C_{IDI}			Leaching to Groundwater	
		Scenario A C_{IDI} mg/kg	Scenario B C_{IDI} mg/kg	Scenario C C_{IDI} mg/kg	C_{LEACH} mg/kg	
Acenapthene	83-32-9	1700	2400	5400	1,000	1.2
Acetone	67-64-1	2,700	3,700	8,700	No GTARC	No GTARC
Acetonitrile	75-05-8	150	200	420	No GTARC	No GTARC
Acifluorfen	62476-59-9	51	71	200	No Kd	0.001
Acrylamide	79-06-1	0.4	0.5	1.0	7.8E-05	1.0E-05
Acrylic Acid	79-10-7	34,000	48,000	110,000	No GTARC	No GTARC
Acrylonitrile	107-13-1	0.8	1.0	2	1.2E-04	6.0E-05
Alachlor	15972-60-8	20	29	81	0.05	0.002
Aldicarb	116-06-3	70	98	230	0.03	0.007
Aldicarb sulfone	1646-88-4	70	98	230	0.02	0.007
Aldrin	309-00-2	0.1	0.1	0.4	0.6	2.0E-06
Allyl alcohol	107-18-6	350	490	1,200	No GTARC	No GTARC
Allyl chloride	107-05-1	3,500	4,900	11,000	No GTARC	No GTARC
Ametryn	834-12-8	630	880	2,100	2.9	0.06
Ammonium sulfamate	7773-06-0	5,600	7,900	18,000	No Kd	2
Anthracene (PAH)	120-12-7	8,500	12,000	27,000	33,000	9.6
Antimony	7440-36-0	85	120	300	No Kd	0.006
Arsenic	7440-38-2	11	11	14	No Kd	0.05
Atrazine	1912-24-9	7	10	29	0.18	0.003
Barium	7440-39-3	14,000	20,000	51,000	1,700	2
Baygon	114-26-1	280	390	920	0.06	0.003
Bentazon	25057-89-0	180	250	580	No Kd	0.2
Benzene	71-43-2	6	8	13	0.05	0.005
Benzidine	92-87-5	0.01	0.01	0.03	0.002	1.2E-07
Benzo(a)anthracene (PAH)	56-55-3	1	2	4	0.2	4.4E-6
Benzo(a)pyrene (PAH)	50-32-8	0.2	0.2	0.6	24	2.0E-04
Benzo(b)fluoranthene (PAH)	205-99-2	0.9	1	4	0.6	4.4E-6
Benzo(k)fluoranthene (PAH)	207-08-9	8	12	32	0.6	4.4E-6
Benzoic Acid	65-85-0	280,000	390,000	920,000	No GTARC	No GTARC
Beryllium	7440-41-7	0.05	0.07	0.2	130	0.004
1,1-Biphenyl	92-52-4	1,400	2,000	4,500	No GTARC	No GTARC
Bis(2-ethylhexyl)phthalate	117-81-7	410	570	1,800	11,000	0.006
Bis(2-chloroethyl) ether	111-44-4	0.5	0.7	2	1.0E-04	3.0E-05
Bis(2-chloroisopropyl) ether	39638-32-9	8	11	27	2.6	0.3
Bis(chloromethyl) ether	542-88-1	0.001	0.002	0.004	3.4E-07	1.6E-07
Boron	7440-42-8	19,000	27,000	68,000	No Kd	0.6
Bromodichloromethane	75-27-4	11	15	41	0.7	0.08
Bromoform	75-25-2	140	200	450	1.0	0.08
4-Bromophenyl phenyl ether	101-55-3	150	150	150	No GTARC	No GTARC
Butyl benzyl phthalate	85-68-7	930	930	930	20,000	3
Cadmium	7440-43-9	110	150	380	11	0.005
Captan	133-06-2	470	660	1,800	No GTARC	No GTARC
Carbaryl	63-25-2	7,000	9,800	23,000	10	0.7
Carbazole	86-74-8	82	110	320	No GTARC	No GTARC
Carbofuran	1563-66-2	350	490	1,200	0.30	0.04
Carbon disulfide	75-15-0	630	721	721	No GTARC	No GTARC
Carbon tetrachloride	56-23-5	2	3	5	0.13	0.005
Carboxin	5234-68-4	7,000	9,800	23,000	No Kd	0.7

Table B1. Soil and Groundwater Target Concentrations (STARC and GTARC)

Chemical	CAS #	Soil Target Concentrations (STARC) (see Appx. B, Sec. 2 & Fig. B2 for guidance in selecting cleanup levels)				Ground-water Target Concns (GTARC) mg/l
		Direct Exposure (Ingestion/Dermal/Inhalation) C_{IDI}			Leaching to Groundwater	
		Scenario A C_{IDI} mg/kg	Scenario B C_{IDI} mg/kg	Scenario C C_{IDI} mg/kg	C_{LEACH} mg/kg	
Chloramben	133-90-4	1,100	1,500	3,500	2.4	0.1
Chlordane	12789-03-6	7	10	30	28	0.002
p-Chloroaniline	106-47-8	280	390	920	No GTARC	No GTARC
Chlorobenzene	108-90-7	66	92	180	2.8	0.1
Chloroform	67-66-3	0.8	1.0	1.0	0.6	0.08
2-Chlorophenol	95-57-8	140	200	450	1.9	0.04
Chlorothalonil	1897-45-6	150	210	590	100	0.15
Chlorpyrifos	2921-88-2	210	290	690	4.4	0.02
Chromium, total	7440-47-3	2,100	3,000	4,500	38	0.1
Chrysene (PAH)	218-01-9	36	52	140	0.2	4.4E-6
Copper	7440-50-8	1,100	3,100	4,700	No Kd	1.3
Cyanazine	21725-46-2	2	3	8	0.06	0.001
Cyanide	57-12-5	5480	7670	20400	39	0.2
Cyanogen bromide	506-68-3	2,500	2,500	2,500	No GTARC	No GTARC
Dalapon, sodium salt	75-99-0	850	850	850	0.4	0.2
2,4-Dichlorophenoxyaceticacid (2,4-D)	94-75-7	1,000	1,500	3,500	No Kd	0.07
DDD	72-54-8	12	17	48	240	0.002
DDE	72-55-9	8	12	34	1,100	0.002
DDT	50-29-3	8	12	34	620	0.002
Demeton	8065-48-3	1	2	4	No GTARC	No GTARC
Diazinon	333-41-5	59	59	59	0.02	6.0E-04
Dibenzo(a,h)anthracene (PAH)	53-70-3	0.2	0.2	0.6	2	4.4E-6
Dibenzofuran	132-64-9	110	160	360	No GTARC	No GTARC
1,4-Dibromobenzene	106-37-6	700	980	2,300	No GTARC	No GTARC
Dibromochloromethane	124-48-1	20	27	77	0.8	0.08
1,2-Dibromo-3-chloropropane	96-12-8	1	2	5	0.001	2.0E-04
Dibutyl phthalate	84-74-2	2,300	2,300	2,300	11,000	2.7
Dicamba	1918-00-9	2,100	2,900	6,900	3.1	0.2
1,2-Dichlorobenzene	95-50-1	600	600	600	45	0.6
1,4-Dichlorobenzene	106-46-7	17	24	51	5.6	0.075
3,3-Dichlorobenzidine	91-94-1	4	5	14	0.003	4.0E-05
1,2-Dichloroethane	107-06-2	2	3	6	0.02	0.005
1,1-Dichloroethylene	75-35-4	0.4	0.6	1	0.09	0.007
cis-1,2-Dichloroethylene	156-59-2	1,200	1,200	1,200	0.5	0.07
trans-1,2-Dichloroethylene	156-60-5	2,900	3,100	3,100	1.0	0.1
2,4-Dichlorophenol	120-83-2	210	290	690	0.4	0.02
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)	94-82-6	560	790	1,800	No GTARC	No GTARC
1,2-Dichloropropane	78-87-5	10	14	25	0.04	0.005
1,3-Dichloropropene	542-75-6	0.9	1	2	0.004	0.0004
Dieldrin	60-57-1	0.1	0.1	0.4	0.005	2.0E-06
Diethyl phthalate	84-66-2	2,000	2,000	2,000	830	23
Dimethoate	60-51-5	14	20	46	No GTARC	No GTARC
Dimethyl phthalate	131-11-3	1,360	1,360	1,360	2,100	313
2,4-Dimethylphenol	105-67-9	1,400	2,000	4,600	14	0.54
2,6-Dimethylphenol	576-26-1	42	59	140	No GTARC	No GTARC
3,4-Dimethylphenol	95-65-8	70	98	230	No GTARC	No GTARC
1,3-Dinitrobenzene	99-65-0	7	10	23	0.01	0.001
2,4-Dinitrophenol	51-28-5	140	200	460	0.14	0.07

Table B1. Soil and Groundwater Target Concentrations (STARC and GTARC)

Chemical	CAS #	Soil Target Concentrations (STARC) (see Appx. B, Sec. 2 & Fig. B2 for guidance in selecting cleanup levels)				Ground-water Target Concns (GTARC) mg/l
		Direct Exposure (Ingestion/Dermal/Inhalation) C_{IDI}			Leaching to Groundwater	
		Scenario A C_{IDI} mg/kg	Scenario B C_{IDI} mg/kg	Scenario C C_{IDI} mg/kg	C_{LEACH} mg/kg	
2,4-Dinitrotoluene	121-14-2	2	3	10	0.0007	5.0E-05
2,6-Dinitrotoluene	606-20-2	2	3	10	5.0E-04	5.0E-05
Di-n-octylphthalate	117-84-0	0.3	0.3	0.3	No GTARC	No GTARC
Dinoseb	88-85-7	70	98	230	0.10	0.007
1,4-Dioxane	123-91-1	150	210	590	0.01	0.003
Diphenamid	957-51-7	2,100	2,900	6,900	No Kd	0.2
Diphenylamine	122-39-4	1,800	2,500	5,800	15	0.2
Diquat	85-00-7	150	220	510	No Kd	0.02
Disulfoton	298-04-4	2	2	2	6.0E-04	3.0E-04
Diuron	330-54-1	140	200	460	0.5	0.01
Endosulfan	115-29-7	420	590	1,400	No GTARC	No GTARC
Endothall	145-73-3	1,400	2,000	4,600	1.6	0.1
Endrin	72-20-8	21	29	69	3.0	0.002
Ethylbenzene	100-41-4	400	400	400	32	0.7
Ethylene glycol	107-21-1	124,000	124,000	124,000	34	14
Ethylene thiourea	96-45-7	6	8	18	6.0E-04	2.0E-04
Fenamiphos	22224-92-6	18	25	57	0.08	0.002
Fluometuron	2164-17-2	910	1,300	3,000	2.0	0.09
Fluoranthene (PAH)	206-44-0	1,600	2,300	5,200	3,800	0.3
Fluorene (PAH)	86-73-7	1,100	1,600	3,600	2,100	1.3
Fonofos	944-22-9	1,400	2,000	4,600	No Kd	0.01
Formaldehyde	50-00-0	14,000	20,000	46,000	No Kd	1
Glyphosate	1071-83-6	7,000	9,800	23,000	300	0.7
Heptachlor	76-44-8	0.3	0.4	0.9	67	4.0E-04
Heptachlor epoxide	1024-57-3	0.2	0.3	0.7	2.0	2.0E-04
Hexachlorobenzene	118-74-1	0.9	1	3	6.5	0.001
Hexachlorobutadiene	87-68-3	14	20	46	6.3	0.001
a-Hexachlorocyclohexane	319-84-6	0.3	0.4	1	3.2E-04	2.2E-06
b-Hexachlorocyclohexane	319-85-7	0.9	1	3	3.3E-04	2.2E-06
g-Hexachlorocyclohexane	58-89-9	1	2	5	0.03	2.0E-04
d-Hexachlorocyclohexane	319-86-8	No tox data	No tox data	No tox data	0.001	2.2E-06
Hexachlorocyclopentadiene	77-47-4	9	13	17	1,200	0.05
Hexachloroethane	67-72-1	70	98	230	0.2	0.001
Hexachlorophene	70-30-4	21	29	70	No GTARC	No GTARC
n-Hexane	110-54-3	110	160	183	No GTARC	No GTARC
Hexazinone	51235-04-2	2,300	3,200	7,600	No Kd	0.4
HMX	2691-41-0	3,500	4,900	12,000	2.5	0.4
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	3	4	11	1.8	4.4E-6
Isophorone	78-59-1	1,700	2,400	4,570	0.7	0.1
Isopropylbenzene	98-82-8	210	210	210	No GTARC	No GTARC
Lead	7439-92-1	260	660	660	No Kd	0.015
Malathion	121-75-5	1,400	1,600	1,600	21	0.1
Maleic anhydride	108-31-6	7,000	9,800	23,000	No GTARC	No GTARC
Maleic hydrazide	123-33-1	35,000	49,000	120,000	27	4
Maneb	12427-38-2	27	38	110	No GTARC	No GTARC
Manganese	7439-96-5	3,700	5,200	11,000	No Kd	0.05
Mercury	7439-97-6	0.6	0.8	1	3.2	0.002
Methamidophos	10265-92-6	4	5	12	No GTARC	No GTARC

Table B1. Soil and Groundwater Target Concentrations (STARC and GTARC)

Chemical	CAS #	Soil Target Concentrations (STARC) (see Appx. B, Sec. 2 & Fig. B2 for guidance in selecting cleanup levels)				Groundwater Target Concns (GTARC) mg/l
		Direct Exposure (Ingestion/Dermal/Inhalation) C_{IDI}			Leaching to Groundwater	
		Scenario A C_{IDI} mg/kg	Scenario B C_{IDI} mg/kg	Scenario C C_{IDI} mg/kg	C_{LEACH} mg/kg	
Methanol	67-56-1	35,000	49,000	120,000	No GTARC	No GTARC
Methomyl	16752-77-5	1,800	2,500	5,800	0.7	0.2
Methoxychlor	72-43-5	350	490	1,200	460	0.04
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	94-74-6	35	49	120	0.05	0.004
Methyl ethyl ketone	78-93-3	7,400	10,000	16,000	No GTARC	No GTARC
Methyl iodide	74-88-4	15,000	15,000	15,000	No GTARC	No GTARC
Methyl isobutyl ketone	108-10-1	1,000	1,500	2,300	No GTARC	No GTARC
Methyl parathion	298-00-0	18	25	58	1.2	0.002
2-Methylphenol	95-48-7	3,500	4,900	12,000	No GTARC	No GTARC
3-Methylphenol	108-39-4	3,500	4,900	7,000	No GTARC	No GTARC
4-Methylphenol	106-44-5	250	350	820	No GTARC	No GTARC
Methylene chloride	75-09-2	51	71	150	0.02	0.005
Methyl tertiary butyl ether (MTBE)	1634-04-4	8760	8760	8760	0.067	0.02
Metolachlor	51218-45-2	11,000	15,000	35,000	No Kd	0.1
Metribuzin	21087-64-9	1,800	2,500	5,800	2.6	0.2
Mirex	2385-85-5	0.9	1	4	No GTARC	No GTARC
Molybdenum	7439-98-7	1,300	1,900	4,900	No Kd	0.04
Naled	300-76-5	140	200	460	No GTARC	No GTARC
Naphthalene (PAH)	91-20-3	120	170	240	24	0.1
Nickel	7440-02-0	4,800	6,700	17,000	170	0.1
Nitrobenzene	98-95-3	12	17	35	0.2	0.017
n-Nitrosodimethylamine	62-75-9	0.03	0.05	0.1	2.4E-06	7.0E-07
n-Nitrosodiphenylamine	86-30-6	330	470	1,300	0.8	0.005
Oxamyl	23135-22-0	1,800	2,500	5,800	0.6	0.2
Paraquat	4685-14-7	320	440	1,000	55	0.03
Pendimethalin	40487-42-1	2,800	3,900	9,300	No GTARC	No GTARC
Pentachlorobenzene	608-93-5	56	79	180	350	0.074
Pentachloronitrobenzene	82-68-8	6	9	25	No GTARC	No GTARC
Pentachlorophenol	87-86-5	6	9	25	0.07	0.001
Phenol	108-95-2	5,200	7,300	17,000	21	4
m-Phenylenediamine	108-45-2	420	590	1,400	No GTARC	No GTARC
Phenylmercuric acetate	62-38-4	6	8	18	No GTARC	No GTARC
Phorate	298-02-2	14	20	46	No GTARC	No GTARC
Picloram	1918-02-1	4,900	6,900	16,000	310	0.5
Polychlorinated biphenyls (PCBs)	1336-36-3	0.6	0.9	2.5	18	5.0E-04
Prometon	1610-18-0	1,100	1,500	3,500	6.4	0.1
Pronamide	23950-58-5	5,300	7,400	17,000	1.3	0.05
Propachlor	1918-16-7	910	1,300	3,000	3.0	0.09
Propanil	709-98-8	350	490	1,200	No GTARC	No GTARC
Propazine	139-40-2	1,400	2,000	4,600	0.2	0.01
Propham	122-42-9	1,400	2,000	4,600	1.2	0.1
n-Propylbenzene	103-65-1	28	40	91	No GTARC	No GTARC
Pyrene (PAH)	129-00-0	2,100	2,900	6,900	12,000	0.96
RDX	121-82-4	15	21	59	No Kd	0.002
Rotenone	83-79-4	280	390	920	No GTARC	No GTARC
Selenium	7782-49-2	300	410	970	4.3	0.05
Silver	7440-22-4	140	200	450	26	0.1
Silvex	93-72-1	560	790	1,800	0.4	0.05

Table B1. Soil and Groundwater Target Concentrations (STARC and GTARC)

Chemical	CAS #	Soil Target Concentrations (STARC) (see Appx. B, Sec. 2 & Fig. B2 for guidance in selecting cleanup levels)				Ground-water Target Concns (GTARC) mg/l
		Direct Exposure (Ingestion/Dermal/Inhalation) C_{IDI}			Leaching to Groundwater	
		Scenario A C_{IDI} mg/kg	Scenario B C_{IDI} mg/kg	Scenario C C_{IDI} mg/kg	C_{LEACH} mg/kg	
Simazine	122-34-9	14	19	54	0.07	0.004
Strontium	7440-24-6	130,000	180,000	460,000	No Kd	4
Strychnine	57-24-9	21	29	69	No GTARC	No GTARC
Styrene	100-42-5	1,500	1,500	1,500	9.4	0.1
Terbacil	5902-51-2	910	1,300	3,000	0.6	0.09
Terbufos	13071-79-9	2	2	6	0.07	9.0E-04
1,1,1,2-Tetrachloroethane	630-20-6	10	13	24	0.8	0.07
1,1,2,2-Tetrachloroethane	79-34-5	2	2	5	0.004	3.0E-04
Tetrachloroethylene	127-18-4	40	55	120	0.1	0.005
Tetrahydrofuran	109-99-9	87	120	330	No GTARC	No GTARC
Thallium Compounds	10031-59-1	17	24	61	2.8	0.002
Toluene	108-88-3	650	650	650	3.7	0.15
Total petroleum hydrocarbons (TPH)	NA	200	500	1,000	No Kd	10
Toxaphene	8001-35-2	1	2	6	91	0.003
Triallate	2303-17-5	54	54	54	No GTARC	No GTARC
1,2,4-Trichlorobenzene	120-82-1	270	380	860	15	0.07
1,3,5-Trichlorobenzene	108-70-3	No tox data	No tox data	No tox data	3.4	0.04
1,1,1-Trichloroethane	71-55-6	1,200	1,200	1,200	3.5	0.2
1,1,2-Trichloroethane	79-00-5	5	7	14	0.04	0.005
Trichloroethylene	79-01-6	40	56	89	0.1	0.005
Trichlorofluoromethane	75-69-4	770	1,100	1,400	No GTARC	No GTARC
2,4,5-Trichlorophenol	95-95-4	7,000	9,800	23,000	500	2.6
2,4,6-Trichlorophenol	88-06-2	140	190	510	0.1	0.003
1,2,3-Trichloropropane	96-18-4	0.09	0.1	0.4	0.3	0.04
1,1,2-Trichlorotrifluoroethane	76-13-1	1,100	1,100	1,100	No GTARC	No GTARC
Trifluralin	1582-09-8	210	300	840	8.1	0.005
1,2,4-Trimethylbenzene	95-63-6	100	140	180	No GTARC	No GTARC
1,3,5-Trimethylbenzene	108-67-8	42	59	76	No GTARC	No GTARC
1,3,5-Trinitrobenzene	99-35-4	2,100	2,900	6,900	No GTARC	No GTARC
2,4,6-Trinitrotoluene	118-96-7	35	49	120	0.08	0.002
Vanadium	7440-62-2	1,500	2,100	5,300	No GTARC	No GTARC
Vinyl chloride	75-01-4	0.3	0.4	0.6	0.02	0.002
Warfarin	81-81-2	21	29	69	No GTARC	No GTARC
White phosphorus	7723-14-0	4	6	15	No Kd	1.0E-04
Xylenes	1330-20-7	418	418	418	16	0.32
Zinc	7440-66-6	38,000	53,000	130,000	3,000	2

NOTES

Scenario A – "Unrestricted" land use including residential
Scenario B – "Commercial" land use; requires institutional controls
Scenario C – "Industrial" land use; requires institutional controls
No tox data – Reliable toxicological data necessary to calculate cleanup levels were not identified for this contaminant.
No GTARC – Groundwater target concentration not available for this contaminant.
No Kd – Reliable partitioning coefficient data necessary for calculating C_{LEACH} was not identified for this contaminant.